Chapter 2

Measuring Green Data Centers

This chapter presents assessment systems used around the world to measure green buildings, formulas for calculating Data Center energy efficiency, and an overview of industry organizations pursuing the development of each. This chapter also offers guidance for putting Data Center metrics in the appropriate context to understand a facility's performance.

Why Measure in the Data Center

There's an often-used management adage that says you can't manage what you don't measure, and it certainly applies to Data Centers.

You not only need to accurately gauge your Data Center's capacity and resources to operate the facility effectively, but you also need to know how quickly you consume those resources and what type and quantity of byproducts the Data Center produces to know how green it is. Taking measurements is also crucial to determine the impact of any green improvements that you make upon the server environment. Without such information you can't know whether those upgrades have been successful, and if so to what extent, how fast their return on investment is, or how to prioritize future Data Center upgrades.

The reason to measure Data Center efficiency might seem obvious, but many companies apparently don't see value in doing so. Surveys of more than 1,500 Data Center owners and operators at DatacenterDynamics conferences in 2008 indicate that fewer than one in three were using a Data Center efficiency metric and fewer than half definitely intended to use them in the future.

Just 461 (30.3 percent) of 1,523 respondents indicated they use a Data Center efficiency metric, according to the Datacenter Research Group that performed the studies, whereas the remaining 1,062 (69.7 percent) reported they did not. When the same group was asked whether they plan to employ efficiency metrics in the future, 642 (42.2 percent) indicated they did whereas 492 (32.3 percent) indicated they did not. The remaining 389 (25.5 percent) did not reply or else indicated that they did not know.

Table 2.1 summarizes the results, broken down by geographic theater. Interestingly, those in the United States appear to be using Data Center metrics most often yet those in Western Europe have the greatest intention to do so in the future.

Table 2.1 *Usage of Data Center Efficiency Metrics*

	United States	Western Europe	Emerging Markets	Total
Number of Respondents	540	792	191	1523
Use a Data Center efficiency metric	225 (41.7%)	177 (22.%)	59 (30.%)	461 (30.3%)
Don't use a Data Center efficiency metric	315 (58.3%)	615 (77.7%)	132 (69.3%)	1062 (69.7%)
Intend to use a Data Center efficiency metric in the future	196 (36.3%)	367 (46.3%)	79 (41.4%)	642 (42.2%)
Do not intend to use a Data Center efficiency metric in the future	190 (35.2%)	249 (31.4%)	53 (27.8%)	492 (32.3%)
Don't know/Did not reply	154 (28.5%)	176 (22.2%)	59 (30.9%)	389 (25.5%)

It's possible that the survey results in Table 2.1 show a greater adoption of Data Center metrics than is truly happening. All the survey participants were, as noted, attendees at Data Center conferences. Companies that commit money and staff time for employees to attend such events are actively seeking Data Center best practices for their facilities. How many more businesses, particularly those with makeshift server environments, aren't sending employees to such conferences and aren't focusing on the efficiency of their facility?

What to Measure in the Data Center

Knowing the importance of taking measurements in your Data Center, what elements are useful to measure to evaluate how green a room is and to quantify the impact of various upgrades? The sections that follow address this question.

Energy Usage

The single-most important resource for you to measure in your Data Center is energy. How much power the facility has and how much power is consumed by both IT equipment and supporting infrastructure such as cooling systems and lighting.

It's vital to measure energy for several reasons:

- **Power is a Data Center's most precious resource:** The small form factor and big energy demands of today's high performance servers mean most Data Centers will run out of power well before cabinet space or cooling. Even if you aren't interested in green considerations, measuring energy usage is critical to understand the true capacity of the room.
- **Power is the common element among disparate Data Center subsystems:** Air handlers, servers, and overhead lighting are all different infrastructure of a Data Center—so different that they're each installed and maintained by personnel that are trained in separate disciplines—yet they all need power to function. Measuring energy consumption creates a common standard by which you can tell how much they're each drawing upon your overall Data Center capacity.
- **Power consumption is the most expensive operational cost of a Data Center:** By measuring the specific energy usage of various Data Center components and applying the regional cost of electricity, you learn the true monthly expense of those components. This enables you to target which Data Center subsystems have the potential to save you the most energy and the most money through efficiency improvements.
- **Power consumption largely defines a Data Center's environmental impact:** The amount of power that a Data Center uses on a day-to-day basis determines how much irreplaceable fossil fuels it consumes and the quantity of carbon emissions it is responsible for.

Because of these four conditions, green Data Center improvements that conserve energy provide some of the largest benefits to your business. Measuring power in your Data Center is, therefore, also the best way to appraise that value and understand the real impact of those green improvements.

Carbon Footprint

Another benchmark of a Data Center's environmental impact is its carbon footprint—the amount of carbon dioxide produced as part of the ongoing operation of the facility.

Carbon dioxide is one of a handful of substances dubbed *greenhouse gases* that trap heat from the sun and warm the Earth. (Water vapor is the most common greenhouse gas, followed by carbon dioxide, methane, nitrous oxide, ozone, and chlorofluorocarbons.)

That warming effect is necessary to a certain degree. Without it, the Earth's mean surface temperature would be –2 degrees Fahrenheit (–19 degrees Celsius) rather than today's 57 degrees Fahrenheit (14 degrees Celsius), according to the Intergovernmental Panel on Climate Change document, "Climate Change 2007: The Physical Science Basis." Too much warming can cause environmental problems, though, changing weather patterns, causing sea levels to rise, and altering the habitats of various animals, plants, and, ultimately, people.

Many scientists and environmentalists today are concerned that human activity is causing such problems, prompting them and various government agencies worldwide to call for reductions in carbon dioxide emissions. Although carbon dioxide occurs naturally—people, animals, and plants all produce it; volcanoes and hot springs emit it as well—carbon is also a byproduct of burning fossil fuels.

More than 80 percent of greenhouse gas emissions in the United States, for example, are energy-related carbon dioxide—originating from the combustion of petroleum, coal, and natural gas—according to the U.S. Department of Energy's Energy Information Administration. (EIA reports of U.S. greenhouse gas emissions are available online for every year since 1996 at http://www.eia.doe.gov/oiaf/1605/ggrpt/index.html.)

The links from energy production to carbon dioxide to climate change mean that the less energy your Data Center uses, the smaller its impact upon the environment.

The other factor in a server environment's carbon footprint is the makeup of the electricity powering the facility. Several sources of energy are used to create electricity, and each generates a different amount of carbon dioxide. Turning coal into electricity produces more carbon dioxide than natural gas, for instance, so your Data Center will have a larger carbon footprint if your regional power company provides electricity derived from coal rather than natural gas. Cleaner energy sources, such as nuclear or hydroelectric power, create minimal amounts of carbon dioxide, so any Data Center powered by those sources, either directly or by way of a utility provider, will have an even smaller carbon footprint.

Carbon Offsets

One strategy for dealing with *carbon emissions* is to employ *carbon offsets*, measures that reduce carbon dioxide. In simple terms, you compensate for the amount of carbon that you (or in this case, your Data Center) generate by sponsoring a project that prevents an equal amount from being created.

Examples of carbon offsets include

- Providing a source of renewable energy, such as biofuels, hydroelectric, solar, or wind power
- Planting trees, which serve as natural carbon sinks
- Capturing and eliminating more potent greenhouse gases, such as methane produced by landfills or pollutants (that is, hydrofluorocarbons or perfluorocarbons) created during industrial processes

Although it's possible to directly introduce carbon-offsetting measures at your Data Center facility—building a wind farm on land that you own, for example—the more common approach is to pay an environmental organization to do the activity.

More information about renewable energy sources and regional electricity mixes is provided in Chapter 4, "Powering Your Way to a Greener Data Center."

Other Data Center Elements

Energy usage and carbon footprint are the features most commonly discussed and measured to determine how green a Data Center is; however, other elements warrant attention as well. Other green details to consider include the following:

- **Generator emissions:** Standby generators, used to keep a Data Center running when commercial power fails, consume fuel when in operation and can emit a range of pollutants including nitrogen oxides, hydrocarbons, carbon monoxide, carbon dioxide, and particulate matter. Knowing the consumption and emissions of your Data Center generators provide greater insight into the facility's environmental impact.
- **Heat waste:** Most strategies regarding Data Center temperatures focus on how to best remove hot server exhaust from the hosting environment yet pay little attention to the ultimate disposition of Data Center heat waste. If your Data Center cooling system is highly efficient and does a superb job of keeping equipment cool but raises temperatures outdoors, how green is it really? Hot building exhaust is blamed for increasing the severity of several undesirable environmental and health problems including air pollution, heat-related illnesses, deteriorated water quality, and increased energy consumption during summer evenings. The phenomenon known as *heat islands* is discussed further in Chapter 3, "Green Design and Build Strategies."
- **Water consumption:** Major Data Centers consume millions of gallons/liters of water per month through standard cooling processes as hot water is vaporized from a Data Center's cooling tower and has to be replaced. (Water used to replace what has evaporated is known as makeup water.) Although this consumption hasn't received the same level of attention from governments and the public in recent years as energy use and carbon emissions, removing such large amounts of water from local supplies is a tremendous environmental impact.

The more of these Data Center elements that you measure, the more opportunities to make your server environment greener that you uncover. Tips on reducing the impact of these features are provided in Chapter 4 and Chapter 5, "Cooling Your Way to a Greener Data Center."

Environmental Building Assessment Systems

The definition of a green Data Center as one that uses resources more efficiently and has less environmental impact is valid as far as it goes, but it comes with a lot of latitude. How much more efficient does a facility need to be before it can be considered green? How much less impact on the environment must it have than a conventional server environment? Five percent? Fifty percent? More?

In its *Seven Sins of Greenwashing* report mentioned in Chapter 1, "Going Green in the Data Center," TerraChoice Environmental Marketing rightly notes that the term *green* is essentially meaningless (and thereby committing its Sin of Vagueness) if not qualified in some manner.

Several environmental building assessment systems have been created in an attempt to quantify and qualify building performance. These assessment systems typically evaluate green features such as energy efficiency, carbon emissions, pollution, water consumption, building material selection, and more. In most assessment systems, a building or building project earns points for features within certain categories and achieves a rating level (for instance, bronze, silver, gold, or platinum) based on the cumulative score. Different assessment programs are popular in various regions of the world. As a group, they offer standards for a range of structures including commercial buildings, residences, schools, prisons, and more. Although these assessment systems were not specifically created to apply to server environments, many Data Center designers and builders look to them as a way to evaluate how green their new projects and existing facilities are. If you have a Data Center or Data Center project in a region where one of these programs is commonly used, consider following their guidelines. Even if your facility doesn't achieve formal certification, all of the building assessment systems generally provide good green principles to follow. Your project can only benefit from considering them.

Several municipalities offer incentives for construction projects that commit to earning a particular rating from whatever environmental building assessment system is prevalent in the area. Typical benefits can include

- Expedited permitting
- Free green building technical assistance
- Fee waivers
- Low interest loans
- Property tax credits

Other governments instead offer disincentives, financially penalizing projects that fail to obtain green building certification.

Note Assuming that building officials aren't requiring you to use a particular environmental building assessment system, there's nothing to stop you from ignoring what is most commonly used in the region in which your Data Center is in favor of another one, but I recommend at least reviewing the local assessment system first. Many of the rating programs reflect the green priorities that are most important in that region.

The building assessment system created and used in a country where droughts occur will stress (and be structured to award points for) water conservation more than a building assessment system developed for a region with ample water, for instance. Even if you don't seek to have your server environment certified under the local program, it's important to understand the value that is placed upon water as you approach your Data Center project.

Building Research Establishment Environmental Assessment Method (BREEAM)

The oldest and most widespread building assessment system is the Building Research Establishment Environmental Assessment Method (BREEAM). The system was created in 1990 by Building Research Establishment, a building research organization originally funded by the United Kingdom government. The organization has since been privatized and is now funded by the building industry.

Of all the building assessment systems, BREEAM has been the most influential. Not only have more than 110,000 buildings been BREEAM certified and more than 500,000 registered through the program, but several other assessment programs favored in various parts of the world also are based to a significant degree on the BREEAM system.

BREEAM is most commonly applied to office buildings and private residences, although standards also exist for schools, industrial buildings, retail facilities, health buildings, court buildings, and prisons. Other structures can also be rated using a customized BREEAM scoring system, known as BREEAM Bespoke.

BREAM assesses building performance according to nine categories:

- **Management:** Site commissioning, contractor issues, and overall policy management
- **Energy use:** Power consumption and carbon emissions, heating and cooling efficiencies and metering
- **Health and well being:** Elements that impact building user comfort and health, such as fresh air ventilation and controls for lighting and temperature
- **Pollution:** Air and water pollution
- **Transport:** Elements to reduce carbon emissions associated with transportation, from the use of local building materials (avoiding the need to ship supplies from far away) to the proximity to public transit to encourage employee usage
- **Land use:** Use of existing facilities rather than undeveloped land, or cleanup of previously contaminated property
- **Ecology:** Ecological conservation or creation of habitat
- **Materials:** Building materials
- **Water:** Water consumption and efficiencies

Buildings are rated on a scale of 1 to 100. Points are awarded for each category, and the total score determines whether a building is rated pass (25 percent), good (40 percent), very good (55 percent), excellent (70 percent), or outstanding (85 percent). The system is designed to measure the environmental impact of a building during its entire lifespan.

Notable amendments were made to BREEAM in 2008. These included changes to the environmental weightings within the system, new benchmarks for carbon dioxide emissions, the addition of minimum requirements for energy and water consumption, and the introduction of the "outstanding" rating level. Building designers can now also receive extra credits for implementing innovative technologies that have environmental benefits.

Also in 2008, a BREEAM certification was awarded for the first time to a Data Center project—a 107,640-square foot (10,000-square meter) Digital Realty Trust facility in suburban London built for financial firm HSBC. The Data Center earned a BREEAM rating of excellent thanks to green design elements ranging from high-efficiency chilled-water cooling and heat recovery systems to the use of solar panels and recycled building materials. More BREEAM certifications for Data Centers can be expected in the future. Having customized its rating criteria for the DRT project, BRE now has it as an ongoing offering under its BREEAM Bespoke category.

You can find more information about BREEAM at www.breeam.org.

Note Most environmental building assessment systems have different rating criteria for existing facilities than for new construction and for various types of buildings—a commercial office building, a school, and a residential building are all likely evaluated according to different factors, for instance. Unless stated otherwise, the assessment system criteria referenced in this book are for new construction and are office building standards, which—lacking more Data Center-specific standards—are the ones typically considered for a Data Center build.

Green Globes

Green Globes, used in Canada and the United States, is one of the environmental building assessment systems that can be traced back to BREEAM. The Canadian Standards Association published BREEAM Canada for Existing Buildings in 1996, with several new elements and capabilities added since then, most notably the online assessment tool Green Globes for Existing Buildings in 2000.

Environmental impact is rated in seven categories:

- **Energy:** Performance, efficiency, demand reduction, energy efficient features, use of renewable energy, and transportation
- **Indoor environment:** Ventilation, lighting, thermal and acoustical comfort, and ventilation system
- **Site impact:** Ecological impact, development area, watershed features, and enhancement
- **Resources:** Low impact materials, reuse, demolition, durability, and recycling
- **Water:** Performance, conservation, and treatment
- **Emissions and effluents:** Air emissions (boilers), ozone depletion, water and sewer protection, and pollution controls
- **Project management:** Design process, environmental purchasing, and commissioning

Although 1,000 points are conceivably available in the Green Globes system, the actual maximum number that can be achieved vary by project.

A key difference between the Canadian and U.S. versions of Green Globes is in the rating levels used. Buildings in Canada are awarded up to five globes whereas those in the United States are awarded up to four. As shown by Table 2.2, the difference comes from the elimination of the bottom scoring category for U.S. projects.

Table 2.2 *Green Globes Ratings*

Percentage	Canada	United States
85 to 100	Five globes	Four globes
70 to 84	Four globes	Three globes
55 to 69	Three globes	Two globes
35 to 54	Two globes	One globe
15 to 34	One globe	—

In Canada, Green Globes for Existing Buildings is owned and operated by the Building Owners and Managers Association of Canada under the brand name Go Green, whereas other Green Globes products are owned and operated by ECD Energy and Environment Canada. In the United States, Green Globes is owned and operated by the Green Building Initiative.

More information about Green Globes is available for the Canadian version at www.greenglobes.com and for the U.S. version at http://www.thegbi.org/.

Haute Qualité Environmentale (HQE)

Green building standards are defined in France by the Haute Qualité Environmentale (High Environmental Quality) approach. *The Association pour la Haute Qualité Environmentale*, formed in 1996, defines 14 target areas for HQE under four themes:

- **Eco-construction:** Relationship between buildings and immediate surroundings, integrated choice of construction products and methods, and low-nuisance construction processes
- **Eco-management:** Energy management, water management, waste management, and maintenance
- **User comfort:** Humidity, acoustics, visual comfort, and odor control
- **User health:** Indoor air quality, water quality, and sanitary treatment

A formal certification program for HQE was developed in 2002 by Centre Scientifique et Technique du Bâtiment. Its three rankings include the following:

- Basic (pass)
- Performant (high performing)
- Très performant (very high performing)

The program applies to offices, schools, hotels, and commercial centers, and there are plans to expand it to other types of buildings in the future.

More information about HQE is available (in French) at http://www.assohqe.org/.

Hong Kong Building Environmental Assessment Method (HK-BEAM)

The Hong Kong Building Environmental Assessment Method was created in 1996 by the Real Estate Developers Association of Hong Kong, based largely upon BREEAM. Originally applied to just new and existing office buildings, HK-BEAM now addresses a wide range of structures including commercial buildings, residential developments, hotels, apartments, hospitals, and municipal buildings.

New building designs are evaluated according to 19 criteria in 5 categories, with a sixth category of bonus credits available for innovations that provide performance enhancements:

- **Site aspects:** Location and design of the building, emissions from the site, and site management
- **Materials aspects:** Selection of materials, efficient use of materials, and waste disposal and recycling
- **Energy use:** Annual energy use, energy-efficient systems and equipment, and energy management
- **Water use:** Water quality, water conservation, and effluent discharges
- **Indoor environmental quality:** Safety, hygiene, indoor air quality and ventilation, thermal comfort, lighting, acoustics and noise, and building amenities
- **Environmental innovations:** Innovative techniques and performance enhancements

HK-BEAM ratings include bronze (40 percent, above average), silver (55 percent, good), gold (65 percent, very good), and platinum (75 percent, excellent).

More than 150 premises, encompassing 70 million square feet (6.5 million square meters) of floor space, have been submitted for HK-BEAM assessment. That includes more than 36,000 residential units, making it the most widely used system of its kind—on a per capita basis—in the world. The program is currently owned and operated by the not-for-profit HK-BEAM Society.

You can find more information about HK-BEAM at http://www.hk-beam.org.hk.

Ecology, Energy Saving, Waste Reduction, and Health (EEWH)

Taiwan's system for assessing green buildings, developed in 1998 by the Ministry of the Interior's Architecture and Building Research Institute (ABRI), takes its name from its four overall focus areas of ecology, energy saving, waste reduction and health. EEWH rates structures according to nine categories:

- **Biodiversity:** Biological habitat, ecological network, plant diversity, and soil ecology
- **Greenery:** Carbon dioxide absorption factor
- **Soil water content:** Permeability
- **Energy conservation:** Air conditioning, building envelope, and lighting energy efficiency
- **Carbon dioxide emission reductions:** Building material selection and construction methods
- **Construction waste reduction:** Solid waste and particle pollution
- **Indoor environmental quality:** Building acoustic environments, lighting and ventilation environments, and building materials
- **Water conservation:** Water savings and recycling
- **Sewage and garbage:** Landscape design, sewer plumbing, and garbage containment sanitation

EEWH has five levels—certified, bronze, silver, gold, and diamond. To qualify as green, a project must at minimum pass the energy and water conservation indicators and any two of the remaining seven.

The Taiwainese government began offering a Green Building Promotion Program in 2001, subsidizing green remodeling projects and air-conditioning efficiency improvements and ultimately requiring that all new public buildings (receiving more than $1.5 million in government funding) achieve green building certification before being allowed to obtain a building license. The program concluded in 2007, by which time more than 1,400 buildings or building projects had been certified as green.

More information about EEWH is available (in Taiwanese and English) at http://www.cabc.org.tw/ or http://www.abri.gov.tw.

The SB Tool

If your company has sites in more than one country, you're probably thinking that it would be nice to have a universal assessment system rather than distinct methods for different parts of the world. The main challenge to this is that geographic regions often prioritize environmental issues and qualities differently from one another. This is typically due to local environmental conditions, abundance or scarcity of various natural resources, and even social values.

One solution is the Sustainable Building (SB) Tool, a generic framework for rating green buildings and projects created through the Sustainable Building Challenge. Originally known as the Green Building (GB) Tool, the SB Tool software enables users to incorporate as many as 125 rating criteria and to weight key parameters to reflect regional priorities.

The Sustainable Building Challenge (first called the Green Building Challenge) began in 1996 to highlight green building design techniques and enable regions to meaningfully compare green building data. More than 20 countries participate in the Sustainable Building Challenge conferences, which are usually held about every 3 years.

You can find more information about the SB Tool and Sustainable Building Challenge at www.iisbe.org.

Leadership in Energy and Environmental Design (LEED)

The Leadership in Energy and Environmental Design building rating system is in use in several countries around the world and, based upon the number of other assessment systems modeled upon it, is second only to BREEAM in terms of influence.

LEED debuted in the United States in 1998 after 4 years of development, and versions of it are now used in several countries including Canada, China, India, Korea, and Spain. More than 20,000 projects encompassing more than 5 billion square feet (464.5 million square meters) of building projects have been registered, seeking LEED certification.

LEED standards are overseen by the U.S. Green Building Council, with the LEED certification process administrated by the Green Building Certification Institute. LEED certifications are applied to a variety of building types including offices, retail and service establishments, institutional buildings (such as libraries, schools, museums, and religious institutions), hotels, and homes.

Adjustments were made to the LEED system in 2009, changing the weighting of various project elements, expanding the scoring system, and introducing new bonus points.

Rating criteria fall into six categories:

- **Sustainable sites:** Site selection, building reuse, alternative transportation measures, protection or restoration of habitat, open space, storm-water design, heat island reduction, and light pollution reduction
- **Water efficiency:** Water use reduction, landscaping, and wastewater technologies
- **Energy and atmosphere:** Energy efficiency, renewable energy, commissioning, refrigerant management, measurement and verification, and green power

- **Materials and resources:** Building reuse, construction waste management, materials reuse, recycled content, regional materials, rapidly renewable materials, and certified wood
- **Indoor environmental quality:** Outdoor air delivery monitoring, ventilation, indoor air quality management planning, low-emitting materials, exposure to indoor pollutants, lighting, thermal comfort, and day lighting
- **Innovation and design:** Exceptional or innovative performance

LEED allows for a degree of customization based upon geography, awarding bonus points for projects that provide "regionally important benefit."

All together, projects can earn up to 110 points. Rating levels include certified (40 points), silver (50 points), gold (60 points), and platinum (80 points).

You can find more information about LEED at http://www.leedbuilding.org/ or http://www.usgbc.org.

LEED Certified Data Centers

Of all the environmental building assessment systems in the world, none has drawn more attention from the Data Center industry than LEED.

Mortgage provider Fannie Mae's Urbana Technology Center, a 247,000-square feet (22,947-square meter) facility in Urbana, Maryland, that includes both server environment and office space was the first Data Center to receive LEED certification. It earned the distinction in 2005 through an energy-efficient design, use of recycled materials and low emission paints and carpeting, sustainable landscaping elements, construction waste recycling, and other green features.

Per the U.S. Green Building Council, at the time of this book's publication, only five Data Centers have received LEED certification, while more than 32 Data Center projects are registered with the intention of becoming LEED-rated upon their completion. More Data Center projects will undoubtedly seek LEED status in the future. For instance, Cisco has five Data Center projects in various stages of planning and design as of this writing, and the charter documents of each project call for achieving LEED certification.

Most server environments that are LEED-rated or registered to become so are part of mixed-use facilities. That's because LEED—as with all general-purpose environmental building assessment systems—can be an awkward fit for standalone Data Centers, awarding points for features that are pertinent for office spaces but not server environments, while not addressing other Data Center characteristics that have major environmental impact.

Interest in having a LEED certification that better addresses Data Center issues is so high that a list of rating criteria has been submitted to the U.S. Green Building Council in hopes the organization will create a formal "LEED for Data Centers" standard, addressing new

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Data Center construction. The California Energy Commission funded development of the criteria list by Lawrence Berkeley National Labs (LBNL), which in turn created it with input from Data Center industry groups including the 7 x 24 Exchange, the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), the Critical Facilities Round Table, The Green Grid, the Silicon Valley Leadership Group, and the Uptime Institute, and Data Center technology companies including Cisco, Emerson Network Power, Google, Hewlett-Packard, IBM, Intel, NetApp, Sun Microsystems, and Yahoo.

As proposed by LBNL and others, the Data Center rating criteria would eliminate traditional LEED credits for alternate transportation measures (bike racks and shower facilities), certain renewable building materials (such as sustainably certifiable wood), and indoor environmental quality measures (such as ventilation, thermal comfort, and daylighting). It would instead offer new credits for mitigating generator and cooling tower noise, reducing water usage, and measuring and reporting Data Center energy efficiency.

Although no specific timeline is in place, U.S. Green Building Council representatives say they do intend to establish specific credits for Data Center projects—perhaps as early as 2010. At press time, the USGBC is developing a working group to pursue the issue. LBNL has meanwhile begun development work on a second set of suggested environmental criteria for LEED that would pertain to existing Data Centers.

National Australian Built Environment Rating System (NABERS)

Although some building assessment systems evaluate efficiency based upon a project's proposed design, the National Australian Built Environment Rating System (NABERS) measures the operational performance of existing buildings.

Introduced in 2001 by the Australian government's Department of Environment and Heritage, NABERS is now managed by the Department of Energy Utilities Sustainability NSW Government.

NABERS evaluates the building's impact upon the broader environment, upon building occupants, and upon the surrounding area, based upon four categories:

- **Energy:** Energy efficiency, greenhouse gas emissions, and renewable energy usage
- **Water:** Water reuse and water consumption per person
- **Waste:** Waste reduction measures
- **Indoor environment:** Acoustic comfort, air quality, thermal comfort, and lighting

Additional NABERS categories that have either been used on a trial basis or are planned for later development include refrigerants, storm-water runoff and pollution, sewage, landscape diversity, transport, and occupant satisfaction.

Buildings are awarded one (poor), two (below average), three (above average), four (excellent), or five (exceptional) stars. A score of 2.5 is considered the median. Ratings are based on a building's performance data for the prior 12 months.

NABERS initially focused on office buildings, homes, and hotels but has since developed ratings for stores, schools, and hospitals. In 2008 NABERS also incorporated the

Australian Building Greenhouse Rating system, which focuses on greenhouse gas emissions and used a similar five-star rating scheme.

You can find more information about NABERS at www.nabers.com.au.

Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)

The Japan Sustainable Building Consortium promotes green building design and upgrades through the use of the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), which it introduced in 2002.

CASBEE is predominantly used in Japan and other parts of Asia. Some local governments now require property owners to include a CASBEE assessment of their building, which the municipality uses to report on sustainable buildings. Some cities have additionally introduced localized versions of CASBEE, customized to reflect local environmental factors or priorities.

CASBEE focuses on four categories: energy efficiency, resource efficiency, local environment, and indoor environment. As part of a CASBEE assessment a building site receives two separate evaluations. One is the building's environmental quality and performance, which encompasses

- **Indoor environment:** Noise and acoustics, thermal comfort, lighting and illumination, and air quality
- **Quality of service:** Service ability, durability and reliability, flexibility, and adaptability
- **Outdoor environment on site:** Biological environment, townscape and landscape, and land characteristics and outdoor amenity

This rating (Q) addresses the conditions for those residing within the building property. The other is the building's environmental loading, which includes

- **Energy:** Building thermal load, natural energy utilization, efficiency in building service system, and efficient operation
- **Resources and materials:** Water resources, reduction of nonrenewable material use, and materials with low health risks
- **Off-site environment:** Global warming, local environment, and surrounding environment

This rating (L) evaluates the environmental impact of the site upon those outside its boundaries.

A building's energy-efficiency score (the BEE in CASBEE) is then calculated by dividing the building's environmental quality and performance (Q) by the building's environmental loadings (L):

$$\text{Building Environmental Efficiency (BEE)} = \frac{\text{Q (Building environmental quality and performance)}}{\text{L (Building environmental loadings)}}$$

Higher scores are achieved by having the most favorable conditions within the building site while having the least environmental impact upon those beyond the site. Buildings receive one of five classes, C (poor), B–, B+, A, and S (excellent).

You can find more information about CASBEE (in Japanese) at www.ibec.or.jp/CASBEE/ or (in English) at www.ibec.or.jp/CASBEE/english/index.htm.

Green Star

Green Star, launched in 2003 and overseen by the Green Building Council of Australia, is a second environmental building rating system used in that country. Where NABERS evaluates the operational performance of existing buildings, Green Star focuses on the design and management processes.

Green Star rating tools are available for several building types, including commercial offices, shopping centers, health-care facilities, multi-unit residential buildings, and schools. Nine criteria are used to rate projects:

- **Management:** Credits address the adoption of sustainable development principles from project conception through design, construction, commissioning, tuning, and operation.
- **Indoor environmental quality:** Credits target environmental impact along with occupant well-being and performance by addressing the air conditioning system, lighting, occupant comfort, and pollutants.
- **Energy:** Credits target reduction of greenhouse gas emissions from building operation by addressing energy demand reduction, use efficiency, and generation from alternative sources.
- **Transport:** Credits reward the reduction of demand for individual cars by both discouraging car commuting and encouraging use of alternative transportation.
- **Water:** Credits address reduction of potable water through efficient design of building services, water reuse, and substitution with other water sources (specifically rainwater).
- **Materials:** Credits target resource consumption through material selection, reuse initiatives, and efficient management practices.
- **Land use and ecology:** Credits address a project's impact on its immediate ecosystem by discouraging degradation and encouraging restoration of flora and fauna.
- **Emissions:** Credits address point source pollution from buildings and building services to the atmosphere, watercourse, and local ecosystems.
- **Innovation:** Green Star seeks to reward marketplace innovation that fosters the industry's transition to sustainable building.

Projects are awarded one through six stars, although the Green Building Council of Australia only certifies buildings that achieve four (best practice), five (Australian excellence), or six (world leadership) stars. Scoring thresholds are one star (10 points), two stars

(20 points), three stars (30 points), four stars (45 points), five stars (60 points), and six stars (75 points). The Green Star scoring of up to 100 points includes environmental weighting factors that differ among Australia's states and territories.

You can find more information about Green Star at http://www.gbcaus.org/au/green-star/.

Green Mark

Singapore's Building and Construction Authority initiated its Green Mark rating system in 2005 to evaluate the environmental impact and performance of new and existing buildings.

Rating criteria include

- **Energy efficiency:** Air conditioning, building envelope, lighting, ventilation, and use of renewable energy
- **Water efficiency:** Water-efficient fittings, water usage and leak detection, irrigation system, and water consumption of cooling tower
- **Environmental protection:** Sustainable construction, greenery, environmental management practice, public transport accessibility, and refrigerants
- **Indoor environmental quality:** Thermal comfort, noise level, indoor air pollutants, and high frequency ballasts
- **Environmental innovations:** Green features and innovations

Projects are scored on a 100-point scale, with four Green Mark ranking levels: certified (50 points), gold (75 points), gold-plus (85 points), and platinum (90 points).

As of 2007, all new public buildings and those undergoing major retrofitting in Singapore have been required to be Green Mark-certified. Singapore additionally offers financial incentives for building projects to be green-certified, setting aside approximately $13 million (20 million Singapore dollars) for 3 years under its Green Mark Incentive Scheme to provide cash incentives of up to 3 million Singapore dollars per building and 100,000 Singapore dollars for engineers and architects to achieve at least a Green Mark Gold rating.

You can find more information about Green Mark at http://www.bca.gov.sg or www.greenmark.sg.

Comprehensive Environmental Performance Assessment Scheme (CEPAS)

HK-BEAM isn't the only building assessment system in use in Hong Kong. The Hong Kong government's Building Department launched a new rating system in 2005, the Comprehensive Environmental Performance Assessment Scheme (CEPAS).

CEPAS evaluates building designs according to 34 criteria in eight categories:

- **Indoor environmental quality:** Health and hygiene, indoor air quality, noise and acoustic environment, and lighting environment
- **Building amenities:** Safety, management, controllability, serviceability, adaptability, and living quality
- **Resources use:** Energy consumption, energy efficiency, use of renewable energy, water conservation, timber use, material use, and building reuse
- **Loadings:** Pollution and waste management
- **Site amenities:** Landscape, cultural character, building economics, and security
- **Neighborhood amenities:** Provisions for the community, transportation, and sustainability economics
- **Site impacts:** Site environment, nature conservation, heritage conservation, and buildability
- **Neighborhood impacts:** Environmental impact assessment, environmental interactions, and impacts to communities

Ratings include unclassified, bronze, silver, gold, and platinum. Certifications are valid for 5 years.

You can find more information about CEPAS (in Chinese) at http://www.bd.gov.hk/chineseT/documents/index_CEPAS.html and (in English) at http://www.bd.gov.hk/english/documents/index_CEPAS.html.

German Sustainable Building Certificate

Germany began awarding green certifications to buildings in 2008, using criteria developed by the German Sustainability Council (the Deutsche Gesellchaft für Nachhaltiges Bauen or DGNB) and the German Federal Ministry of Transport, Building and Urban Affairs (the Bundesministerium für Verkehr, Bau und Stadtentwicklung or BMVBS)

Unlike other building assessment systems, the German Sustainable Building Certificate focuses not only on environmental impacts but also on economic performance, socio-cultural aspects, and functional aspects of buildings.

DGNB criteria fall into six categories:

- **Ecological quality:** Global warming potential, ozone depletion potential, photochemical ozone creation potential, acidification potential, eutrophication potential, risks to the regional environment, other impacts to the global environment, microclimate, nonrenewable primary energy demands, total primary energy demands and proportion of renewable primary energy, potable water consumption and sewage generation, and surface area usage
- **Economical quality:** Building-related lifecycle costs and value stability
- **Socio-cultural and functional quality:** Thermal comfort, indoor hygiene, acoustical comfort, visual comfort, influences by users, roof design, safety and risks of failure, barrier free accessibility, area efficiency, feasibility of conversion, accessibility, bicycle

comfort, assurance of the quality of design and for urban development for competition, and art within architecture

- **Technical quality:** Fire protection, noise protection, energetic and moisture proofing quality of the building's shell, ease of cleaning and maintenance of the structure, and ease of deconstruction, recycling, and dismantling
- **Process quality:** Quality of the project's preparation, integral planning, optimization and complexity of the approach to planning, evidence of sustainability considerations during bid invitation and awarding, establishment of preconditions for optimized use and operation, construction site and phase, quality of executing companies and pre-qualifications, quality assurance of the construction activities, and systematic commissioning
- **Quality of the location:** Risks at the microlocation, circumstances at the microlocation, image and condition of the location and neighborhood, connection to transportation, vicinity to usage-specific facilities, and adjoining media, and infrastructure development

Certain criteria are weighted more heavily than others. Scores from the first five categories, from which a maximum of 855 points can be earned, determine a project's rating of bronze (50 percent), silver (65 percent), or gold (80 percent). Projects are alternatively given grades of 5.0 (20 percent), 4.0 (35 percent), 3.0 (50 percent), 2.0 (65 percent), 1.5 (80 percent), or 1.0 (95 percent). The certificate's sixth category, location, is listed separately from a project's rating, as a percentage of a total possible 130 points.

Certification was originally applied to only office and administrative buildings but has since been expanded to other types of construction.

You can find more information about DGNB (in German) at www.dgnb.de/.

Summary of Environmental Building Assessment Systems

Table 2.3 summarizes, in alphabetical order, green building assessment systems in use around the world.

Note While building assessment systems are valuable for setting green targets for building owners, designers, and construction personnel to aspire to, they are sometimes an awkward fit for Data Centers. Consider two of the LEED credits suggested for removal by LBNL and others in order to create a Data Center-specific certification, for instance, daylighting and alternative transportation. If a structure is a fully dedicated Data Center building, containing no general office space, the physical security needs of the server environment are going to preclude the presence of skylights or windows bringing outdoor light inside, thereby eliminating the chance of earning daylighting credits. Meanwhile, supporting alternate transportation by providing secure bike racks and shower and changing facilities is admirable, but it's not a very good indicator of whether a Data Center is green.

Although such mismatches don't make it impossible to achieve a green certification—as proven by the Data Centers that have secured LEED ratings—don't lose sight of your ultimate goal in the design of your green Data Center. Don't chase points in any assessment system by introducing design or operational elements that don't benefit your Data Center. Likewise, don't avoid useful measures just because they won't earn points.

Table 2.3 *Building Assessment System Criteria and Ratings*

System	BREEAM	CASBEE	CEPAS	EEWH	German Sustainable Building Certificate	Green Globes
Countries	UK, others	Japan	Hong Kong	Taiwan	Germany	Canada, U.S.
Year Introduced	1990	2002	2005	1998	2008	1996 (BREEAM Canada)
Criteria	Management Energy use Health and well-being Pollution Transport Land use Ecology Materials Water	Q (Environmental Quality) Indoor environment Quality of service On-site outdoor environment L (Environmental loading) Energy Resources and materials Off-site environment	Indoor environmental quality Building amenities Resources use Loadings Site amenities Neighborhood amenities Site impacts Neighborhood impacts	Biodiversity Greenery Soil water content Energy conservation Carbon emission reductions Construction waste reduction Indoor environmental quality Water conservation Sewage and garbage	Ecological quality Economical quality Social quality Technical quality Quality of the process Quality of the location	Energy Indoor environment Site impact Resources Water Emissions and effluents Project management
Ratings	Pass Good Very good Excellent Outstanding	C (poor) B B+ A S (excellent)	Unclassified Bronze Silver Gold Platinum	Certified Bronze Silver Gold Diamond	Bronze Silver Gold	One globe Two globes Three globes Four globes (U.S. maximum) Five globes (Canada maximum)

System	*Green Mark*	*Green Star*	*HQE*	*HK-BEAM*	*LEED*	*NABERS*
Countries	**Singapore**	**Australia**	**France**	**Hong Kong**	**U.S., others**	**Australia**
Year Introduced	*2005*	*2003*	*1996*	*1996*	*1998*	*2001*
Criteria	Energy efficiency Water efficiency Environmental protection Indoor environmental quality Environmental innovations	Management Indoor environmental quality Energy Transport Water Materials Land use and ecology Emissions Innovation	Relationship between buildings and immediate surroundings Integrated choice of construction products and methods Low-nuisance construction processes Energy management Water management Waste management and maintenance Humidity Acoustics Visual comfort Odor control Indoor air quality Water quality Sanitary treatment	Site aspects Materials aspects Energy aspects Water aspects Indoor environmental quality Environmental innovations	Sustainable sites Water efficiency Energy and atmosphere Materials and resources Indoor environmental quality Innovation and design process Regional bonus credits	Energy Water waste Indoor environment

continues

Table 2.3 *Building Assessment System Criteria and Ratings (continued)*

System	*Green Mark*	*Green Star*	*HQE*	*HK-BEAM*	*LEED*	*NABERS*
Countries	**Singapore**	**Australia**	**France**	**Hong Kong**	**U.S., others**	**Australia**
Ratings	Certified Gold Gold-plus Platinum	One stars Two stars Three stars Four stars (best practice) Five stars (Australian excellence) Six stars (World leadership)	Base (basic) Performant (high performing) Très performant (very high performing)	Bronze Silver Gold Platinum	Certified Silver Gold Platinum	One star (poor) Two stars (good) Three stars (very good) Four stars (excellent) Five stars (exceptional)

Organizations Influencing Green Data Center Metrics

Although environmental building assessment systems don't typically focus upon server environments, a handful of organizations are actively developing or promoting Data Center-specific metrics to pinpoint how green these facilities are.

Keep an eye on their activities and published works to stay current on what metrics are prominent in the industry today or might be coming in the future. The sections that follow cover the most notable agencies and their influential green activities. A broader list of entities that are doing work relevant to the design and operation of a green Data Center is provided in the Appendix, "Sources of Data Center Green Information."

The European Commission

The European Union is ahead of most other regions of the world with its focus on energy efficiency, reducing greenhouse gas emissions, and other environmental concerns. As mentioned in Chapter 1, the European Commission has developed a voluntary Data Center Code of Conduct to promote Data Center energy efficiency, passed an EU Energy Performance Building Directive, adopted an Eco-design Directive for Energy Using Products, and set energy and carbon emission reduction goals for its member countries.

The Commission, which is the executive branch of the EU, has also formulated individual Codes of Conduct pertaining to the electrical efficiency of broadband equipment, digital television equipment, power supplies of electronic and electrical appliances, and UPS systems.

Additional environmental directives from the European Commission, whether in the form of legal mandates or voluntary programs, will undoubtedly follow in the future with some influencing the Data Center industry.

You can find more information about the European Commission's environmental legislation (in multiple languages) at http://ec.europa.eu/environment/index.htm.

The Green Grid

The Green Grid is a global consortium of companies focused upon Data Center energy efficiency. Launched in 2007, the group's more than 150 members include a broad range of Data Center hardware and software manufacturers. (Cisco is one of them.)

The group's stated goals and activities are

- Defining meaningful, user-centric models and metrics
- Developing standards, measurement methods, processes, and new technologies to improve performance against the defined metrics
- Promoting the adoption of energy-efficient standards processes, measurements, and technologies

The group has issued several whitepapers on Data Center energy efficiency metrics—including power usage effectiveness (PUE) and Data Center infrastructure efficiency (DCIE), detailed elsewhere in this chapter.

At press time, the Green Grid's board of directors includes Advanced Micro Devices (AMD), American Power Conversion (APC), Dell, EMC, Hewlett-Packard (HP), IBM, Intel, Microsoft, and Sun Microsystems.

You can find more information on the Green Grid (in English) at http://www.thegreengrid.org/home or (in Japanese) at http://www.thegreengrid.org/japanese/home.

Uptime Institute

The Uptime Institute is a prominent Data Center education and consulting organization best known for its widely adopted Data Center tier classification system. Launched in 1993, the organization's Site Uptime Network includes more than 100-member companies that share operational and design best practices based upon their real-world experience. (Cisco has been an Uptime participant since 2001, and an official member since 2003.)

Much like the Data Center industry as a whole, the Uptime Institute originally concentrated on Data Center availability, but in recent years has devoted attention to energy efficiency and environmental considerations. The organization regularly hosts seminars and has authored several whitepapers on green Data Center topics. In 2008, the Uptime

Institute also launched a Green Enterprise IT Awards program to recognize Data Center energy efficiencies by companies.

You can find more information about the Uptime Institute at http://www.uptimeinstitute.org/.

The U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency has focused on environmental consideration and energy efficiency for decades and in recent years has turned attention to the Data Center industry. The EPA is currently in the midst of creating a series of energy-efficiency standards for Data Center facilities and the hardware housed within them under its Energy Star label.

The Energy Star program, begun in 1992 to highlight energy efficient products, was initially applied to computers and monitors and later expanded—involving participation from the U.S. Department of Energy and applying to office equipment, major appliances, lighting, home electronics, new homes, commercial and industrial buildings, and more.

At press time, the EPA is gathering data on energy use and operating characteristics from dozens of server environments, both standalone facilities and those in mixed-use buildings, to develop the Energy Star rating for Data Centers. More than 60 companies have shared information on approximately 120 Data Centers, including geographic location (to determine climate influences), function, assumed reliability (using the Uptime Institute's tier classification system), and a year's worth of data on IT power consumption and total facility energy usage.

The EPA rating methodology for Data Centers will be similar to that of its building program, scoring facilities on a 100-point scale and giving the Energy Star designation to those that achieve at least 75 points. A building's energy performance is compared to equivalent structures across the United States—not other facilities in the program—and each point represents a percentile of performance. The system is to be applicable for both Data Center-only and mixed-use buildings.

Note Cisco contributed information from two of its Data Centers for the Energy Star program—a Tier II, 10,000-square foot (929-square meter) facility in Mountain View, California, and a Tier III, 30,000-square foot (2,787-square meter) facility in Richardson, Texas.

By 2008, the energy performance of more than 62,000 buildings were tracked by the Energy Star's online Portfolio Manager tool, and more than 4,000 had been awarded the Energy Star label, with those structures typically using 35 percent less energy than average buildings. The EPA intends to add a Data Center Infrastructure Rating to the Portfolio Manager tool by 2010. Chapter 8, "Choosing Greener Gear," provides details on the Energy Star standard for servers that was issued in 2009, and efforts to develop future standards for storage devices and networking hardware. You can find more information about all of the Data Center-related Energy Star programs at www.energystar.gov/datacenters.

Data Center Green Metrics

Data Center managers have long desired a way to accurately, yet simply, capture the efficiency of their server environments. In essence, how green the rooms are. Often compared to the miles-per-gallon ratings given to automobiles sold in the United States, Data Center efficiency metrics help both IT and Facilities personnel to better understand the performance of their server environment.

Data Center metrics are by and large still evolving. Even those that are the most widely used today are relatively young, introduced only a handful of years ago. New formulas continue to be developed and proposed every few years, most often by Data Center industry groups or technology consulting firms, whereas existing metrics are refined and clarified by their authors on an ongoing basis. The sections that follow outline metrics that capture key Data Center efficiency and environmental characteristics and are worthy candidates to consider using for your server environment.

Power Usage Effectiveness (PUE)

The Data Center metric enjoying the most widespread use these days is Power Usage Effectiveness (PUE), which gauges the electrical efficiency of a server environment by focusing on its electrical overhead.

Created by members of The Green Grid in 2006, PUE divides a facility's total power draw by the amount of power used solely by the Data Center's IT equipment:

$$\text{Power Usage Effectiveness (PUE)} = \frac{\text{Total Facility Power}}{\text{IT Equipment Power}}$$

IT equipment power includes that which is consumed by servers, networking devices, storage units, and peripheral items such as monitors or workstation machines—any equipment used to manage, process, store, or route data in the Data Center.

Total facility power includes that IT equipment plus all Data Center-related primary electrical systems (power distribution units, and electrical switching gear), standby power systems (uninterruptible power sources [UPS]), air-conditioning components (chillers, air handlers, water pumps, and cooling towers), and other infrastructure such as lighting and keyboard, video, and mouse (KVM) equipment.

The lower a Data Center's PUE, the more efficient it is considered to be. That's because a lower PUE indicates that a greater portion of the power going to a Data Center is used for its essential mission—processing and storing information. For example, a PUE of 1.5 means a Data Center needs half-again as much power to operate as is solely needed for the IT equipment whereas a PUE of 3.0 means a Data Center needs twice as much additional power for non-IT elements as it does for IT hardware.

A perfect (and in reality, unattainable) PUE score is 1.0, which represents a server environment in which all the power provided to it is used by IT equipment.

When calculated, PUE can be applied down to the level of a single machine. If a server draws 500 watts and the Data Center's PUE is 1.5, for instance, the room will draw 750 watts to power the machine. Put that same server in a Data Center with a PUE of 3.0, and the room will draw 1,500 watts to power it.

Opinions differ regarding what is a typical Data Center PUE rating. Various Data Center industry groups have suggested 2.0, 2.5, or even 3.0 are common ratings.

Although PUE is sometimes discussed as a static number for a Data Center, it actually varies over time—even during a span as brief as a few hours. Server loads change throughout the day. The rise and fall of external temperatures can also influence how hard a Data Center's cooling system must work—and therefore how much energy it consumes—to regulate the room's temperatures. The IT equipment power profile of a Data Center also changes over time as new devices replace older systems.

Sample PUE Calculations

The following are PUE measurements for two sample Data Centers:

Data Center A actively draws 7,500 kW of total power. Of that, 3,100 kW are consumed by its IT equipment. That facility has a PUE score of 2.4:

Total Facility Power = 7,500 kW

IT Equipment Power = 3,100 kW

7500 / 3100 = 2.4 PUE

Data Center B draws 12,250 kw of total power. Of that, 6,700 kw are consumed by its IT equipment. That facility has a PUE score of 1.8:

Total Facility Power = 12,250 kW

IT Equipment Power = 6,700 kW

12250 / 6700 = 1.8 PUE

Although Data Center B consumes more energy than Data Center A—12,250 kW compared to 7,500 kW—on a proportional basis more of its power goes to IT gear, so from that perspective it is considered more efficient.

Data Center Infrastructure Efficiency (DCIE)

A second metric regarding Data Center electrical efficiency is Data Center Infrastructure Efficiency (DCIE). DCIE is the reciprocal of PUE: The same values are used, but their positions in the formula are inverted. IT equipment power is divided by total facility power. (If you've already calculated PUE, you can also determine DCIE by dividing 1 by the PUE value.) DCIE is expressed as a percentage:

$$\text{Data Center Infrastructure Efficiency (DCIE)} = \frac{\text{IT Equipment Power}}{\text{Total Facility Power}}$$

Because DCIE and PUE involve the same data, they're just different ways to look at the same information. For example, a Data Center with a PUE of 1.5 has a DCIE of 66 percent (1 / 1.5 = 66 percent). PUE highlights that it takes half-again as much power to operate the Data Center as is needed by its IT equipment. DCIE illustrates that two-thirds (66 percent) of the Data Center power is consumed by the IT equipment.

Note Data Center Infrastructure Efficiency was originally known as just Data Center Efficiency or DCE. The Green Grid, which advocates use of the metric and PUE, added the word infrastructure to clear up what it considered misunderstandings over the term Data Center Efficiency. The metric itself did not change.

Although PUE is more commonly used today, some people prefer DCIE because Data Centers with greater electrical efficiency achieve a higher score than less efficient facilities rather than scoring lower, as happens with PUE.

Sample DCIE Calculations

Continuing with the two sample Data Centers used to illustrate PUE, the following are their PUE and DCIE percentages:

As before, Data Center A draws 7,500 kW of total power. Of that, 3,100 kW are consumed by its IT equipment. That facility has a PUE score of 2.4 and a DCIE score of 41.33 percent:

Total Facility Power = 7,500 kW

IT Equipment Power = 3,100 kW

7500 / 3100 = 2.4 PUE

3100 / 7500 = 41.33 percent DCIE

As before, Data Center B draws 12,250 kw of total power. Of that, 6,700 kw are consumed by its IT equipment. That facility has a PUE score of 1.8 and a DCIE score of 54.69 percent:

Total Facility Power = 12,250 kW

IT Equipment Power = 6,700 kW

12250 / 6700 = 1.8 PUE

6700 / 12250 = 54.69 percent DCIE

One quirk of PUE and DCIE is that a Data Center's score can potentially suffer if you implement efficiency measures that reduce the power drawn by your IT equipment.

For instance, say that in Data Center A you consolidate servers by way of a significant virtualization project—discussed in Chapter 9, "Greening Your Data Center Through Consolidation, Virtualization, and Automation"—and in doing so you reduce your server power usage by 300 kW. That adjusts the IT equipment power load in Data Center A from 3,100 kW to 2,800 kW—a 9.7 percent reduction. If the building's facility infrastructure is closely aligned to the IT load and scales with it, it could conceivably see a similar 9.7-percent reduction in total facility power consumption, saving 726 kW and maintaining the Data Center's PUE and DCIE scores at 2.4. It's just as likely, though, that the facility infrastructure isn't in exact step with the IT demand, so the total facility power won't be reduced as much. Say that removal of 300 kW in IT equipment power equates to just 450 kW in total facility power load savings (a 6-percent gain rather than 9.7 percent), reducing it from 7,500 to 7,050 kW. This worsens its PUE from 2.4 to 2.5 and its DCIE from 41.33 percent to 39.72 percent. You've reduced power consumption by the IT equipment by nearly 10 percent (300 kW out of 3,100 kW), but your efficiency metrics look worse.

Tip Just as you shouldn't chase points offered in an environmental building assessment system by adding design elements that don't truly make your Data Center greener, don't let a desire for impressive Data Center metrics deter you from optimizing the power consumption of your IT equipment. You want your Data Center to be as green and slim on energy usage as possible even if building assessment systems and power-efficiency formulas can't reflect it.

Assessment systems and metrics will undoubtedly be developed in the future that showcase those efficiencies. Until then, you can always document the energy you are saving around your IT equipment and include it as a footnote to your PUE and DCIE numbers.

Data Center Energy Profiler

As part of its Save Energy Now program, the U.S. Department of Energy offers an online tool to help assess Data Center energy efficiency. Known as the Data Center Energy Profiler (DC Pro), the application defines a server environment's energy usage based upon information provided by the user and offers design and operational tips for improving efficiency.

Users answer more than 80 questions about the design and operations of their Data Center ranging from physical size, geographic location, and level of redundant electrical infrastructure to details about server lifecycles, use of virtualization, and air-conditioning set points. The tool uses the data to calculate a DCIE score for the server environment and then suggests measures to improve the rating.

The Department of Energy hopes to have thousands of Data Centers assessed by DC Pro and—by following the tool's recommendations—for 1,500 facilities to improve their energy efficiency by an average 25 percent by 2011 and 200 to improve their energy efficiency by an average 50 percent.

DC Pro was developed with contributions from Lawrence Berkeley National Laboratory (LBNL), Ancis Inc., EYP Mission Critical, Rumsey Engineers, Taylor Engineering, and Project Performance Corporation.

You can find more information about the Data Center Energy Profiler at www.eere.energy.gov/datacenters.

Compute Power Efficiency (CPE)

Another approach to evaluating a Data Center's performance is to calculate its electrical overhead and then factor in the average CPU utilization of the servers it houses. Known as Compute Power Efficiency (CPE), this metric was first introduced in 2007:

$$\text{Compute Power Efficiency (CPE)} = \frac{\text{IT Equipment Utilization} \times \text{IT Equipment Power}}{\text{Total Facility Power}}$$

CPE builds off of PUE, so it's no surprise that it was also created by members of The Green Grid. In fact, if you know a Data Center's PUE score, you can divide the average IT equipment utilization by that score as another way to calculate its CPE. Because PUE scores are typically rounded off at one number past the decimal place, CPE and other metrics that incorporate PUE are more precise when you use the original IT equipment and total facility power figures rather than the PUE score itself.

Sample CPE Calculations

The following are the PUE, DCIE, and CPE metrics for the two sample Data Centers mentioned previously:

As before, Data Center A draws 7,500 kW of total power. Of that, 3,100 kW are consumed by its IT equipment. CPU utilization for the servers in that Data Center averages 10 percent. That facility has a PUE score of 2.4, a DCIE score of 41.33 percent, and a CPE score of 4.13 percent:

Total Facility Power = 7,500 kW

IT Equipment Power = 3,100 kW

IT Utilization = 10 percent

7500 / 3100 = 2.4 PUE

3100 / 7500 = 41.33 percent DCIE

10 percent × 3100 / 7500 = 4.13 percent CPE

As before, Data Center B draws 12,250 kw of total power. Of that, 6,700 kw are consumed by its IT equipment. CPU utilization for the servers in that Data Center averages 5 percent. That facility has a PUE score of 1.8, a DCIE score of 54.69 percent, and a CPE score of 2.73 percent:

Total Facility Power = 12,250 kW

IT Equipment Power = 6,700 kW

IT Utilization = 5 percent

12250 / 6700 = 1.8 PUE

6700 / 12250 = 54.69 percent DCIE

5 percent × 6700 / 12250 = 2.73 percent CPE

Technology Carbon Efficiency (TCE)

For another look at how green a Data Center is, multiply the room's electrical efficiency by the carbon emissions factor of the energy powering it. Called Technology Carbon Efficiency (TCE), this metric was introduced in 2007 by CS Technology.

As mentioned in the beginning of this chapter, a variety of energy sources are used to produce electricity and the exact electrical mix that comes from your regional power provider influences the carbon footprint of your Data Center. Combining that emissions factor with the server environment's power efficiency shows how many pounds of carbon dioxide are produced for every kilowatt hour of energy delivered to your IT equipment:

$$\text{Technology Carbon Efficiency (TCE)} = \frac{\text{Total Facility Power}}{\text{IT Equipment Power}} \times \text{Electricity Carbon Emission Rate}$$

As with PUE, the lower a TCE score a Data Center has, the better.

Besides effectively illustrating the relationship between energy use and carbon emissions at a given Data Center, TCE is also useful for showing how different facilities can have similar overall environmental impact. For instance, a server environment with a very efficient PUE rating, but whose electricity comes mostly from coal might have the same or even worse TCE than one with a mediocre (higher) PUE score yet powered by a hydroelectric source.

Sample TCE Calculations

The following are the PUE, DCIE, CPE, and TCE metrics for the two sample Data Centers:

Data Center A draws 7,500 kW of total power. Of that, 3,100 kW are consumed by its IT equipment. CPU utilization for the servers in that Data Center averages 10 percent. Say that Data Center is located in Silicon Valley, which has a carbon emissions rate of 0.71299 pounds of carbon dioxide per kWh of electricity produced.

That facility has a PUE score of 2.4, a DCIE score of 41.33 percent, a CPE score of 4.13 percent, and a TCE score of 1.725:

Total Facility Power = 7,500 kW

IT Equipment Power = 3,100 kW

IT Utilization = 10 percent

7500 / 3100 = 2.4 PUE

3100 / 7500 = 41.33 percent DCIE

10 percent × 3100 / 7500 = 4.13 percent CPE

7500 / 3100 × 0.71299 = 1.725 TCE

Data Center B draws 12,250 kw of total power. Of that, 6,700 kw are consumed by its IT equipment. CPU utilization for the servers in that Data Center averages 5 percent. Say that

Data Center is located in the central part of Texas, which has a carbon emissions rate of 1.32435 pounds of carbon dioxide per kWh of electricity produced.

That facility has a PUE score of 1.8, a DCIE score of 54.69 percent, a CPE score of 2.73 percent, and a TCE score of 2.421:

Total Facility Power = 12,250 kW

IT Equipment Power = 6,700 kW

IT Utilization = 5 percent

12250 / 6700 = 1.8 PUE

6700 / 12250 = 54.69 percent DCIE

5 percent × 6700 / 12250 = 2.73 percent CPE

12250 / 6700 × 1.32435 = 2.421 TCE

Although Data Center A has a much higher (worse) PUE than Data Center B, the mix of electricity powering that facility produces much less carbon, so its TCE is less (better).

Obviously, you can only calculate TCE if you know the carbon emissions rate of the power that is supplying your Data Center. Chapter 4 provides information about regional electricity mixes, including their carbon emission rates. (Carbon emission rates used in the sample TCE calculations are provided in Table 4.3 of Chapter 4, except shown in pounds per MWh rather than pounds per kWh. Silicon Valley is within the California-Mexico Power Area, abbreviated as CAMX in the table, and central Texas is within the region governed by the Electric Reliability Council of Texas, abbreviated as ERCT.)

Corporate Average Data Center Efficiency (CADE)

Looking for a way to measure Data Center performance in a way that encompasses both IT and Facilities technologies, management consulting firm McKinsey & Co. and the Uptime Institute introduced the Corporate Average Data Center Efficiency (CADE) metric in 2008.

CADE uses the same three factors as CPE and proposes a fourth aspect to be developed in the future:

- **Facility energy efficiency:** How much of the power the Data Center is drawing from the electric grid is being used by IT equipment
- **Facility asset utilization:** How much of the Data Center's maximum electrical capacity is in use
- **IT asset utilization:** The average CPU utilization of servers in the Data Center
- **IT energy efficiency:** This measurement hasn't been formulated yet, but is intended to capture how fully servers, networking equipment, and storage units use the power they are drawing to perform their functions

Combining the first two factors determines the efficiency of the facility; combining the second two determines the efficiency of the IT assets. Each factor is expressed as a percentage and then multiplied by the others:

Corporate Average Data Center Efficiency (CADE) = Facility Efficiency (FE) x Asset Efficiency (AE)

Facility Efficiency = Facility Energy Efficiency x Facility Utilization

Asset Efficiency = IT Energy Efficiency x IT Utilization

The greater proportion of a Data Center's power draw that is used by IT equipment and the closer a Data Center is to operating at its maximum electrical capacity and the higher CPU utilization of its servers, the higher (and better) its CADE score.

CADE's facility energy-efficiency component has the same quirk that PUE and DCIE do in that IT energy savings can potentially lower that portion of your score, but this is largely offset by its IT utilization component. Virtualization projects that lower the facility energy-efficiency score, for instance, in turn increase the IT utilization score.

When calculated, CADE scores are then rated on a tier system:

- Level one (0 percent to 5 percent)
- Level two (5 percent to 10 percent)
- Level three (10 percent to 20 percent)
- Level four (20 percent to 40 percent)
- Level five (greater than 40 percent)

During their initial presentation of the metric, McKinsey and Uptime predicted many Data Centers would receive level one or two CADE scores.

Sample CADE Calculations

Continuing with the two sample Data Centers used to illustrate the other metrics:

The following are the PUE, DCIE, CPE, TCE, and CADE metrics for the two sample Data Centers:

Data Center A draws 7,500 kW of total power. Of that, 3,100 kW are consumed by its IT equipment. CPU utilization for the servers in that Data Center averages 10 percent. Say that Data Center is located in Silicon Valley, which has a carbon emissions rate of 0.71299 pounds of carbon dioxide per kWh of electricity produced.

That facility has a PUE score of 2.4, a DCIE score of 41.33 percent, a CPE score of 4.13 percent, a TCE score of 1.725, and a CADE score of 2.6 percent:

Total Facility Power = 7,500 kW

IT Equipment Power = 3,100 kW

IT Utilization = 10 percent

Data Center Capacity = 5,000 kW

7500 / 3100 = 2.4 PUE

3100 / 7500 = 41.33 percent DCIE

10 percent × 3100 / 7500 = 4.13 percent CPE

7500 / 3100 × 0.71299 = 1.725 TCE

3100 / 7500 = 41.3 percent Facility Energy Efficiency

3100 / 5000 = 62 percent Facility Utilization

41.3 percent × 62 percent = 25.6 percent Facility Efficiency

25.6 percent Facility Efficiency × 10 percent IT Asset Efficiency = 2.6 percent CADE

Data Center B draws 12,250 kw of total power. Of that, 6,700 kw are consumed by its IT equipment. CPU utilization for the servers in that Data Center averages 5 percent. Say that Data Center is located in the central part of Texas, which has a carbon emissions rate of 1.32435 pounds of carbon dioxide per kWh of electricity produced.

That facility has a PUE score of 1.8, a DCIE score of 54.69 percent, a CPE score of 2.73 percent, a TCE score of 2.421, and a CADE score of 1.8 percent:

Total Facility Power = 12,250 kW

IT Equipment Power = 6,700 kW

IT Utilization = 5 percent

Data Center Capacity = 10,000 kW

12250 / 6700 = 1.8 PUE

6700 / 12250 = 54.69 percent DCIE

5 percent × 6700 / 12250 = 2.73 percent CPE

12250 / 6700 × 1.32435 = 2.421 TCE

6700 / 12250 = 54.7 percent Facility Energy Efficiency

6700 / 10000 = 67 percent Facility Utilization

54.7 percent × 67 percent = 36.6 percent Facility Efficiency

36.6 percent Facility Efficiency × 5 percent IT Asset Efficiency = 1.8 percent CADE

Data Center A and B each rate as level one on the CADE tiering system.

The IT energy efficiency factor is not included in the sample CADE calculations because that value has not yet been developed. Expect the CADE metric and tiering system to be modified to some degree when it is defined and added to the equation. If nothing else, CADE scores overall can be expected to drop because IT energy-efficiency scores are invariably going to score less than 100 percent.

Data Center Productivity (DCP)

The Green Grid in 2008 proposed a framework for future Data Center metrics under the umbrella of Data Center Productivity (DCP). DCP metrics not only measure the consumption of a Data Center-related resource, as most Data Center efficiency metrics do, but also tally that against the Data Center's output. In short, DCP looks to define what a Data Center accomplishes relative to what it consumes:

$$\text{Data Center Productivity (DCP)} = \frac{\text{Useful Work Produced by Data Center}}{\text{Resource Consumed Producing the Work}}$$

The framework is intended to be applicable for a range of Data Center capacities, from power—which is explored in the Green Grid's inaugural DCP metric, Data Center Energy Productivity—to other Data Center resources such as floor space.

Monitor www.thegreengrid.com and Data Center industry publications for the latest information about development of metrics under the DCP umbrella.

Usage of Metrics

Whatever metrics you opt to gather concerning your Data Center and whatever metric scores you come upon for Data Centers that belong to other companies, they are meaningful only when they can be viewed in context. It's not enough to see that a Data Center has a particular score, you need to understand the conditions and circumstances behind the score and any potential caveats of the metric formulas being used. Consider the following potential variables:

- **There is more than one way to collect data:** Power readings can be taken at different component levels, with different frequency, using tools with different levels of precision.
- **Scores will vary over time:** As already mentioned, the amount of power consumed by Data Center hardware changes throughout the course of a day as different processing tasks begin and end. Also, under many metric formulas, the same Data Center can register as less efficient when it is partially filled with servers than when more fully occupied. That's because some mechanical and electrical components run less efficiently when partially loaded and also because certain supporting infrastructure (minimal amounts of lighting and conditioning, for instance) inherently represent a larger percentage of total power demand in a lightly occupied facility.
- **Redundancy influences scores:** More layers of standby electrical infrastructure reduce downtime but also reduce metric scores due to additional power loss.
- **Geography influences scores:** Some Data Centers will have an easier or harder time conserving energy than others based solely on where they are located. Data Centers in warmer climates have less opportunity to improve energy efficiency by drawing upon external air than Data Centers in cooler climates, for instance. Likewise, a Data

Center in a region where commercial power is unreliable might have to provide more redundant electrical infrastructure, thereby incurring more power loss.

Data Centers aren't created equal—and are, in fact, unequal in so many ways that it's unwise to compare their metrics. The Green Grid says as much in its 2009 whitepaper, "Usage and Public Reporting Guidelines for The Green Grid's Infrastructure Metrics (PUE/DCIE)":

> "Each Data Center has individual characteristics, capabilities, and operational policies that will affect its power performance. In addition, each Data Center also has different capabilities with respect to collecting and analyzing power consumption data. Without additional information about reported results, interpretations of data collected by different organizations using different approaches over different timeframes may be meaningless or misleading."

To reduce the variation in how its PUE and DCIE metrics are calculated, The Green Grid in that 2009 document outlines standard data collection methodology, offering three levels of complexity. The most basic approach calls for taking power readings at least monthly at a Data Center's UPS equipment and the main distribution panel for its air conditioning system; the most advanced approach involves taking continuous power readings from all individual IT hardware and all facility equipment. The Green Grid further suggests annotating PUE and DCIE metrics to indicate which of the three approaches have been used.

With no value in comparing Data Center metrics across facilities, the true benefit in keeping metrics of your Data Center is to gain insight into that particular facility's efficiency relative to its unique circumstances. As Data Center conditions change in the future, either due to green improvement projects that you implement or simply as new hardware is installed over time, maintaining Data Center metrics enables you to understand how the efficiency of the facility changes and perhaps influence your future operational practices or choices for future green upgrades.

Summary

It's necessary to measure your Data Center's capacity and resource consumption to understand how green it is and the impact—financially and consumption-wise—of any upgrades that you make.

Power is the most critical element to track because it is a finite resource needed for a Data Center to function; it is a common platform across IT and facility systems; and its ongoing cost for your facility represents a tremendous opportunity for savings. Another way of quantifying a Data Center's environmental impact is to measure its carbon footprint, which is derived from the amount of energy the facility uses and the electrical mix that powers it. Generator emissions, heat waste, and water consumption are other key indicators of how green a Data Center is.

A growing number in the Data Center industry are now using environmental building assessment systems to gauge the efficiency of their server environments. The rating systems aren't configured to address Data Centers in particular, but do evaluate general green characteristics such as energy efficiency, carbon emissions, pollution, water consumption, building material selection, and more. Some cities reward projects whose facilities are built for certification by an environmental building assessment system, offering them fast-tracked permitting, green technical assistance, fee waivers, low interest loans, and tax credits.

Among the environmental building assessment systems in use worldwide are the UK's Building Research Establishment Environmental Assessment Method (BREEAM); Green Globes in the United States and Canada; France's Haute Qualité Environmentale (HQE); the Hong Kong Building Environmental Assessment Method (HK-BEAM); Taiwan's Ecology, Energy Saving, Waste Reduction and Health (EEWH); the United States' Leadership in Energy and Environmental Design (LEED); and the National Australian Built Environmental Rating System (NABERS)—also, Japan's Comprehensive Assessment System for Building Environmental Efficiency (CASBEE); Australia's Green Star; Hong Kong's Comprehensive Environmental Performance Assessment Scheme (CEPAS); Singapore's Green Mark; and the German Sustainable Building Certificate. Of those, only the BREEAM system has a Data Center-specific standard today; the U.S. Green Building Council is developing one for the LEED system.

Organizations to look to for current or future Data Center efficiency metrics include the European Commission, with its Data Center Code of Conduct; Data Center industry groups the Green Grid and the Uptime Institute; and the U.S. Environmental Protection Agency and its individual Energy Star programs for Data Centers and servers.

Informative and popular Data Center metrics used today include the following:

- **Power Usage Effectiveness (PUE):** Dividing total facility power by IT equipment power
- **Data Center Infrastructure Efficiency (DCIE):** Dividing IT equipment power by total facility power
- **Compute Power Efficiency (CPE):** Multiplying IT equipment utilization by IT equipment power and dividing by total facility power
- **Technology Carbon Efficiency (TCE):** Multiplying PUE by carbon emissions factor
- **Corporate Average Data Center Efficiency (CADE):** Multiplying facility efficiency by IT asset efficiency
- **Data Center Productivity (DCP):** Dividing the useful work produced by a Data Center by the resource consumed producing the work.

Each Data Center has unique factors that influence their metric scores. Data can be collected in different ways; scores change over time as processing loads rise and fall; and both infrastructure redundancy and geographic location influence scores. Don't compare scores among Data Centers, but instead use metrics to better understand and drive improvements within your own specific facility.